

U.S. PATENT APPLICATION

for

SOUND GENERATOR CIRCUIT PRE-FILTER SYSTEM AND METHOD

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SOUND GENERATOR CIRCUIT PRE-FILTER SYSTEM AND METHOD

FIELD OF THE INVENTION

[0001] The invention relates to sound generators typically used in computing devices. In particular, the invention relates to a software pre-filter for a sound generating circuit, the pre-filter being a software pre-filter. Further, the invention relates to a compact sound generator circuit using a software pre-filter for a personal digital assistant. Yet further still, the invention relates to a method of improving the sound quality of a simple sound generator.

BACKGROUND OF THE INVENTION

[0002] Hand held computing devices, "palmtops", or "palmhelds", personal digital assistants (PDAs), or hand held computers typically weight less than a pound and fit in a pocket. These palmhelds generally provide some combination of personal information management, database functions, word processing, and spreadsheets. Because of the small size and portability of palmhelds, strict adherence to hardware constraints, such as sound generation hardware, must be maintained. It is conventional to use a sound generator in a palmheld device which is configured to operate ideally at a particular single frequency, rather than across a broad audio frequency range. When the sound generator is used across the audio frequency range, it provides "poor sound quality" with a widely varying sound pressure level over the audio frequency range for the same user setting.

[0003] Other conventional implementations of sound generation circuits include a dynamic speaker that is designed to operate

across an audio frequency range having a substantially flat frequency response across the range. Such dynamic speakers are physically larger and cost many times more than sound generators. Further, the dynamic speaker drive circuit is also more complicated and expensive to implement than simple sound generators.

[0004] Accordingly, there is a need for a compact sound generator circuit that utilizes a software pre-filter to improve sound quality over an audible frequency range. Further, there is a need for a method of pre-filtering sound generator circuit signals in order to provide improved sound quality using a compact sound generator circuit.

[0005] The teachings herein below extend to those embodiments which fall within the scope of the appended claims, regardless of whether they accomplish one or more of the above mentioned needs.

SUMMARY OF THE INVENTION

[0006] An exemplary embodiment relates to an apparatus configured to improve sound quality for a sound generator. The apparatus includes a processing device and a memory coupled to the processing device. The apparatus also includes a sound generator coupled to the processing device. The apparatus also includes a program residing in memory and configured to be run on the processing device. The program is configured to vary the output amplitude of the sound generator depending on the sound generator frequency.

[0007] Another exemplary embodiment relates to a sound generator circuit. The sound generator circuit includes a processor and a memory coupled to the processor. The sound generator circuit also includes a modulator circuit coupled to the processor. The sound generator circuit further includes a transistor coupled to the modulator circuit. Further still, the sound generator circuit includes a sound

generator coupled to the transistor. Yet further still, the sound generator circuit includes a program residing in memory and configured to be run on the processor. The program is configured to vary the output amplitude of the sound generator depending on the sound generator frequency.

[0008] Further, an exemplary embodiment relates to a method of improving sound quality for a sound generator. The method includes providing a signal indicative of a sound frequency to be generated. The method also includes accessing a lookup table according to the sound frequency to be generated to obtain volume adjusted information. The method further includes providing the current volume setting and adjusting the volume based on the volume adjustment information.

[0009] Further still, an exemplary embodiment relates to a method of improving sound quality for a sound generator. The method includes providing a signal indicative of a sound frequency to be generated. The method also includes calculating volume adjustment information according to the sound frequency to be generated. Further, the method includes providing the current volume setting. Further still, the method includes adjusting the volume based on the volume adjustment information.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] The invention will become more fully understood from the following detailed description, taken in conjunction with the accompanying drawings, wherein like reference numerals refer to like elements, in which:

[0011] FIG. 1 is a depiction of a hand held computer;

[0012] FIG. 2 is an exemplary block diagram of a communications bus architecture for a hand held computer;

[0013] FIG. 3 is an exemplary partial circuit diagram of a sound generator circuit;

[0014] FIG. 4 is a graphical depiction of the frequency response of an exemplary sound generator; and

[0015] FIG. 5 is a graphical depiction of the frequency response of an exemplary sound generator using an exemplary pre-filter and without using a pre-filter.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0016] Referring to FIG. 1, a hand held computer 100 is depicted, being optionally detachably coupled to an accessory device 110 according to an exemplary embodiment. Hand held computer 100 may include Palm style computers such as, but not limited to, Palm Pilot™, Palm III™, Palm IIIc™, Palm V™, Palm VII™, and Palm M100™ organizers, manufactured by Palm, Inc., of Santa Clara, CA. Other exemplary embodiments of the invention may include Windows CE™ hand held computers, or other hand held computers and personal digital assistants, as well as cellular telephones, and other mobile computing devices. Further, hand held computer 100 may be configured with or without accessory device 110 or optionally with any of a variety of other accessory devices.

[0017] Preferably, hand held computer 100 includes interactive hardware and software that performs functions such as maintaining calendars, phone lists, task lists, notepads, calculation applications, spreadsheets, games, and other applications capable of running on a computing device. Hand held computer 100, shown in FIG. 1 includes a plurality of input functions, keys 117 and a display 113 having graphical user interface features. Display 113 may be provided with an interface that allows a user to select and alter displayed content using a pointer, such as, but not limited to, a stylus. In an exemplary

embodiment, display 113 also includes a Graffiti™ writing section 118, or other handwriting recognition software, for tracing alphanumeric characters as input. A plurality of input buttons 119 for performing automated or preprogrammed functions may be provided on a portion of display 113. In a particular embodiment, display 113 is a touch screen display that is electronically responsive to movements of a stylus on the surface of display 113.

[0018] Accessory device 110 may be one of several types of accessories, such as, but not limited to, a modem device for serial and/or wireless data communications, a Universal Serial Bus (USB) device, or a communication cradle having an extended housing. Accessory device 110 may include one or more ports for parallel and/or serial data transfer with other computers or data networks. Hand held computer 100 may use the accessory device 110 for the purpose of downloading and uploading software and for synchronizing data on hand held computer 100 with a personal computer, for example. Accessory device 110 couples to hand held computer 100 through an electrical connector located at a bottom portion of its front face. Button 155 on accessory 110 may effectuate an electrical connection between accessory device 110 and hand held computer 100 when the two are connected.

[0019] Referring to FIG. 2, an exemplary block diagram of a communications bus architecture 200 for a hand held computer, such as hand held computer 100, is depicted. Communications bus architecture 200 includes a processor 210 coupled to a communications bus 215. A memory 220, a sound generator circuit 230, a display controller 240, and various input/output (I/O) devices and ports 260 are all coupled to communications bus 215. Further, a display device 250 is coupled to display controller 240 which is coupled to communications bus 215. Processor 210 is configured to run programs stored in memory 220 and to selectively provide sound, as required through a sound generator

circuit 230. Further, display device 250 is configured to display information as necessary according to the program running on processor 210 and instructions from display controller 240. Input/output devices and ports 260 are used to provide communication and access to any of a number of and/or a variety of input/output devices, such as, but not limited to, printers, network connections, storage devices, other hand held computers, wireless devices, cellular devices, modems, and the like. Sound generator circuit 230 may be any of a variety of sound generators generating circuits including, but not limited to buzzers, and other sound generating devices such as speaker-based devices and the like.

[0020] Referring now to FIG. 3, an exemplary sound generator circuit 300 is depicted. Sound generator circuit 300 includes a buzzer 310, such as, but not limited to a Bujeon BCT-03SR buzzer available from Bujeon Components Company, Limited of Ansan City, Gyunggi-do, Korea, a Citisound CHB-03F available from Citizen Electronics Company, Limited of Kamikurechi Fujiyoshida-shi Yamanashi-ken, Japan, or any of a variety of other buzzer or sound generation devices. Sound generation circuit 300 includes a battery high input 320 for providing a voltage input to buzzer 310 and a pulse width modulated current (PWM) input 330 receiving a modulated input from a PWM as controlled by a processor, such as, but not limited to a DragonBall™ processor, available from Motorola, Inc. of Austin, Texas or any of a variety of other processor or processing devices (in an exemplary embodiment the PWM may be incorporated into the processor). Circuit 300 also includes a transistor, shown as darlington transistor 340 providing switching to buzzer 310 according to the PWM signal received. Transistor 340 is configured to alternately drive the current through buzzer 310 or to short buzzer 310 to ground 350. Circuit 300 also includes a capacitor 360 for filtering out high frequency signals and a resistor 365 and capacitor 370 combination also for filtering out high frequency signals. Further still,

circuit 300 includes a current limiting resistor 375 configured to limit high current signals received from the PWM. Circuit 300 is exemplary of any of a variety of sound generation circuits and is not included to limit the scope of the claims but has been included to show one possible implementation thereof.

[0021] Referring now to FIG. 4, an exemplary frequency response graph is depicted for a sound generator, such as buzzer 310. In particular, graph 400 is the frequency response for a CHB-03F Citisound sound generator. Line 410 depicts the amplitude (sound pressure level) of the tone generated on the Y axis at the frequency provided along the X axis. Inspection of graph 400 reveals that the sound amplitude generated varies widely over the frequency response range. A maximum sound pressure level (or amplitude) occurs at approximately 2.7 kilohertz. In a particular embodiment, sound generator circuit 300 is utilized in a palmheld device or hand held computer in which an exemplary audible range is used from about 500 hertz to 7 kilohertz, however, other audible ranges or frequency ranges of interest may be used.

[0022] Without the improvement described herein, the volume for a hand held computer is set to a particular level by the user ranging, for example, from 1 to 7. Different tones are played in sequence by buzzer 310 at the fixed volume setting for different durations to create the hand held sounds or tunes. Because each tone has a different sound pressure level (or amplitude) with some widely varying, an inconsistent sound level is produced. For example, as depicted in graph 400, a 1.6 kilohertz tone has a sound pressure level of around 81 decibels while a 2.7 kilohertz tone has a sound pressure level of around 96 decibels. This variation of sound pressure level over frequency degrades the sound quality by misrepresenting the tone being played. The use of a software pre-filter may be configured to change the volume at particular frequencies to provide a flatter frequency response curve. An exemplary

implementation of the software pre-filter uses a look-up table of frequencies versus adjustment amount of volume to reduce. An exemplary look-up table for a hand held computer using the CHB-03F Citisound sound generator is shown below.

Frequency	Adjustment
0	0
256	0
512	1
768	1
1024	2
1280	1
1536	1
1792	0
2048	0
2304	1
2560	2
2816	3
3072	3
3328	2
3584	2
3840	1
4096	0
4352	0
4608	1
4864	2
5120	2
5376	3
5632	3
5888	3
6144	3
6400	2
6656	2
6912	1
7168	0
7424	0

[0023] In an exemplary embodiment, the table above is calibrated for a volume setting of 7. Because the volume can be changed by a user, the adjustment amount must also change by the same ratio. Accordingly, the equation to scale the adjustment amount over volume is provided in the program code below;

```
// Calculate the amplitude adjustment based on the amplitude and frequency passed in.  
// This attempts to level the frequency response.  
// if ampAdjMapIndex is in the middle or greater then go to the next ampAdjMapIndex.  
ampAdjTableIndex = (Frq + 128) >> 8;
```

```
if (ampAdjTableIndex >= AmpAdjTableSize-1) // limit index to end of table  
    ampAdj = ampAdjTable[AmpAdjTableSize-1];  
else  
    ampAdj = (ampAdjTable[ampAdjTableIndex]*volume) / volumeMax;  
            // scale adjust over volume.
```

```
//The adjustment value is subtracted from the volume for that particular tone as shown  
//below in equation 2.
```

```
//Equation 2
```

```
adjustedVolume = volume - ampAdj;
```

[0024] Once adjusted volume has been calculated in equation 2, the use of the adjustedVolume gives a flatter frequency response. In an exemplary embodiment the frequency response may not be completely flat due to quantization error in the table and because of the limited volume steps, for example, 1 – 7, that are being used. However, improvement over the use of an unfiltered sound generator is affected. It should be noted that the quantization of the table and the number of volume steps may differ depending on the hardware configurations and software configurations used and the flatness of the frequency response desired. Use of the software pre-filter described above provides an audible improvement in sound for alarms, games, etc. in hand held computing devices and other devices using sound generators, such as buzzers 310 while not requiring complex or costly hardware improvements.

[0025] Referring now to FIG. 5, an exemplary frequency response graph 500 is depicted. Frequency response graph 500 depicts the response of a buzzer, such as 310 without using a software pre-filter as described above. Frequency response 510 is seen as relatively choppy in comparison with frequency response 520, which is the frequency

response of a buzzer utilizing a software pre-filter as discussed above. Frequency response 520 is relatively flat having a response generally in the range of 75 decibels to 78 decibels in the usable range which is from approximately 1 kilohertz to 7 kilohertz in this example. However, any of a variety of usable ranges may be designed, depending on the hardware and software constraints and configurations used. Frequency response 510, which does not use a pre-filter has a range of 75 to 84 decibels in the usable range of 1 kilohertz to 7 kilohertz, which is clearly a much larger range as compared with frequency response 520. Accordingly, the example depicted in FIG. 5 shows the clear advantage of utilizing a pre-filter as discussed above to flatten the frequency response of the buzzer sound system for a hand held computer. Utilizing the pre-filter in the example depicted in FIG. 5, a range of 3 decibels is achieved whereas without using the pre-filter, the buzzer achieves a range of 9 decibels in the usable range from 1 kilohertz to 7 kilohertz.

[0026] While the detailed drawings, specific examples and particular formulations given describe exemplary embodiments, they serve the purpose of illustration only. The hardware and software configurations shown and described may differ depending on the chosen performance characteristics and physical characteristics of the computing devices. For example, the type of computing device, communications bus, or processor used may differ. The systems shown and described are not limited to the precise details and conditions disclosed. Furthermore, other substitutions, modifications, changes, and omissions may be made in the design, operating conditions, and arrangement of the exemplary embodiments without departing from the scope of the invention as expressed in the appended claims.